PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION.

Improvements in or relating to Diaphragms for Acoustic Devices.

We, ELECTRIC & MUSICAL INDUSTRIES LIMITED, a British Company, of Blyth Road, Hayes, Middlesex, and GILBERT FARRADAY DUTTON, a British Subject, of 57, Redcliffe Road, South Kensington, London, S.W. 10, do hereby declare the nature of this invention to be as follows:—

The present invention relates to acoustic devices and more particularly to large diaphragms, that is to say diaphragms of a size adapted to radiate sound effectively without the aid of a horn, and to arrangements for supporting such diaphragms.

Hitherto large conical or frusto-conical diaphragms have usually been made of paper and in some cases these have been corrugated. The response of loudspeakers with paper diaphragms has, however, not been entirely satisfactory at the higher acoustic frequencies and efforts have been made to utilise materials, such as aluminium, having a higher ratio of Young's modulus to density. In this way the lowest frequency at which the diaphragm vibrates in radial modes has been considerably increased. A conical or frusto-conical diaphragm is said to vibrate in a radial mode when one diameter increases as another decreases. The high frequency response has been improved in this way but the diaphragm emits crackling noises when operated at other than very small amplitudes.

It has also been proposed to use a frusto-conical metal diaphragm having a small number of widely spaced concentric depressions or half-corrugations with uncorrugated portions between them.

A further proposal has been to use a diaphragm of aluminium or aluminium alloy having continuous corrugations in its surface. The corrugations, however, were of such shape and depth that portions thereof lay substantially in planes normal to the direction of vibration of the diaphragm.

The crackling noises seem to be due to buckling, that is to say the metal sheet composing the diaphragm is not perfectly smooth and portions of the surface buckle when compressive stress is applied to the diaphragm.

It is an object of the present invention to provide a metal diaphragm in which the disadvantage above referred to is removed.

According to the present invention a large acoustic diaphragm is formed of a material having a higher ratio of Young's modulus to density than paper and has corrugations merging into one another over at least a part of its surface, the ratio of the pitch of the corrugations, to the depth thereof, measured from crest to trough, being greater than 5 and usually considerably greater than this.

According to a feature of this invention as applied to diaphragms of dished shape, for example frusto-conical diaphragms, the shape and depth of the corrugations is made such that all parts thereof lie at a considerable angle to planes normal to the direction of vibration of the diaphragm. The region around the driving point or zone is preferably either uncorrugated or has corrugations of smaller depth than those in a region further from this point or zone. Preferably, with a diaphragm of frusto-conical or other dished shape, the inner corrugations, if provided, are of greater pitch than the outer ones. Where the region around the driving point or zone is uncorrugated it may be made of thicker material than the outer portion of the diaphragm. Alternatively this region may be rendered sufficiently rigid by flaring the smaller diameter end of the conical frustum.

When vibrated at high frequencies, say from about 1,500 cycles per second upyards, a cone of, for example, 10 cms. radius acts in the manner of a mechanical transmission line, the impedance of which increases from the centre outwards. In order to avoid the formation of pronounced standing waves in the diaphragm, the latter must represent a smooth mechanical transmission line. It is therefore necessary to avoid a sudden change of mechanical impedance along the cone radius, such as would occur if the corrugations were deep. The corrugations should consequently be made as shallow as possible, consistent with freedom from rattle. It is also necessary to

terminate the mechanical line with a suitable resistive element of approximately the same impedance as the cone.

In this way the formation of pronounced standing waves due to reflection from the periphery of the diaphragm is prevented.

The corrugations need not be concentric with respect to the cone or with respect to the driving point or zone, and in some instances it is preferred to make them eccentric. A preferred arrangement to prevent appreciable reflection from the periphery is to mount the edge of the diaphragm within a circular aperture in a box or baffle with the aid of an annulus of velvet or the like, there being interposed between the annulus and the diaphragm a layer of a substance which offers high internal friction to vibrations and which is capable of withstanding considerable distortion within the elastic limit. Such a substance is for example Chatterton's Compound. The diaphragm edge is also preferably secured to the velvet by means of this compound but may also be stitched thereto.

In order to damp out circumferential vibrations, the diaphragm may be formed with one or more joints, a substance such as Chatterton's Compound being used for jointing purposes.

In some cases with frusto-conical diaphragms it has been found advantageous to arrange that the plane of the base of the conical frustum is inclined at an acute angle to the axis, instead of at right angles thereto as in the normal arrangement.

In carrying the invention into effect we may proceed as follows:—

A circular sheet of aluminium of about 20 cms. in diameter and with a central hole has a sector cut from it and is formed in known manner into a conical frustum by joining the two radial edges. The size of the sector removed may be such that the angle of the frustum is about 105°. The aluminium may have the following properties:—

Breaking stress with the grain 10 tons per square inch,

Breaking stress across the grain 9 tons per square inch,

Young's modulus 7.3×10^{11} dynes per square centimeter,

Thickness 0.002 inches.

The thickness may vary from the above value by about 15% in either direction. Radial modes have been found to become prominent in diaphragms of the kind to be described if the thickness exceeds 0.003 inches and the diaphragm becomes too fragile if the thickness is below 0.0015 inches.

The value of the square root of the ratio of Young's modulus to density for this quality of aluminium is about 5.1×10^5 cms./sec. whereas the corresponding value for paper is about 1.7×10^5 cms./sec.

The joint in the conical frustum is made by cementing for example with Chatterton's Compound and the joint may also be stitched if desired.

The frustum is then placed in a press and corrugated and the smaller diameter end is simultaneously formed into a cylindrical spigot to receive a driving coil.

The corrugations are in this case concentric with the cone and extend from the periphery inwards for about two thirds of the distance from the periphery to the spigot. The corrugations are formed by merging arcs of 0.4″ radius, their depth measured from crest to trough being 0.015″. The pitch of these corrugations is thus about 0.3″ and the ratio of the pitch to the depth is about 20. Further, the corrugations are all of such shape and depth that no parts thereof approach parallelism to planes normal to the direction of vibration of the diaphragm as a whole, that is planes normal to the axis of the frustum. The remainder of the surface of the cone is preferably uncorrugated.

The aluminium used in constructing the above diaphragm is known as semi-hard. If harder material is used it will be found to have become too hard (and therefore liable to fracture in use) after the corrugations have been formed if these are formed in the cold. A softer material has not sufficient strength to withstand sudden low frequency impulses such as may be met with in practice. If the material is annealed during the corrugating process it may be possible to use a harder material. In any case endeavour should be made to arrange that when the corrugating process has been finished the material of the diaphragm has the highest possible degree of hardness consistent with capacity to resist alternating stress without fracture.

The diaphragm is supported at its centre in known manner by means of a spider or the like and it is mounted within an aperture in a box or baffle with the aid of a ring of flexible material such as velvet. The velvet is secured to the edge of the diaphragm with the interposition of a layer of Chatterton's Compound or like material which is capable of exerting a highly damped restoring force when distorted. The diaphragm may also be stitched to the velvet and the velvet may also be impregnated with

Chatterton's Compound if desired. The Chatterton Compound should in each case preferably be used hot.

The leads to the driving coil should not be secured to the diaphragm as this may lead to rattling.

The thickness of the material may be made greater in the uncorrugated zone than elsewhere or else the smaller diameter end of the frustum may be flared about a relatively large radius into the cylindrical spigot. Thus the metal of the spigot may be put into compression and the zone immediately surrounding this spigot may be placed in tension.

If desired the conical frustum may be formed without joint from a flat sheet by a series of deformations interspersed with annealing operations.

In a modified diaphragm according to this invention, which however has not been found quite so satisfactory as that already described, the size and material are the same but the corrugations over the outer two thirds of the diaphragm surface are formed by merging arcs of 0.21″ radiusand are of depth, from crest to trough, of 0.04″. In this case the pitch is about 0.36″ and the ratio of pitch to depth is therefore about 9. The inner one third of the cone surface is provided with a little more than one shallow corrugation of about 0.03″ in depth formed by merging arcs of 1.25″ radius. The pitch is thus about 0.75″ and the ratio of pitch to depth is 25.

Instead of the corrugations in the diaphragm being of only two different pitches, the pitch may become progressively smaller from the centre region around the driving coil outwards. The depth of the corrugations may also increase progressively from the centre outwards.

The functions of the corrugations are to remove irregularities from the surface of the diaphragm, to increase the lowest frequency at which radial modes of vibration take place and to give the diaphragm the stiffness necessary for safe handling. It is therefore important that, at least in the outer region of the diaphragm, the corrugations should merge into one another and should not be spaced widely apart by uncorrugated portions.

If it is desired to use a flat diaphragm, this is provided with concentric corrugations which preferably extend, merging into one another, from the driving point or zone outwards to the periphery. The corrugations are preferably formed by merging into one another arcs of comparatively large radius, the pitch of the inner corrugation or corrugations around the driven zone being greater than the pitch of the outer corrugations and the depth of the former is preferably less than that of the latter.

Dated this 15th day of Nov., 1932.

REDDIE & GROSE,
Agents for the Applicants,
6, Bream's Buildings, London, E.C. 4.

COMPLETE SPECIFICATION.

Improvements in or relating to Diaphragms for Acoustic Devices.

We, ELECTRIC & MUSICAL INDUSTRIES LIMITED, a British Company, of Blyth Road, Hayes, Middlesex, and GILBERT FARRADAY DUTTON, a British Subject, of 57, Redcliffe Road, South Kensington, London, S.W. 10, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to acoustic devices and more particularly to large diaphragms, that is to say diaphragms of a size adapted to radiate sound effectively without the aid of a horn, and to arrangements for supporting such diaphragms.

Hitherto large conical diaphragms have usually been made of paper, and in some cases these have been corrugated. It has usually been found that such a paper diaphragm can be made thick enough to prevent undue trouble due to the formation of radial modes at low frequencies. A diaphragm is said to vibrate in a radial mode when one part thereof vibrates relatively to another part thereof in such a manner that nodes and antinodes lie along a radial line on the diaphragm. These radial modes do not assist radiation, since simple air-flow takes place from one moving surface to the adjacent oppositely moving surface. There is however, a reaction on the actuating means which tends to increase the effective mass of the diaphragm, and hence the final response characteristic curve of the diaphragm will show a depression at the frequency at which a radial mode occurs.

Vibration in radial modes produces bending stresses in the diaphragm; hence increasing the thickness of the diaphragm raises the frequency at which the radial mode occurs; and the introduction of internal friction damps the vibrations.

A diaphragm of paper having a density of 0.7 gram per cubic centimetre can be made 0.02 inch thick without being unduly heavy. Such a diaphragm is very stiff as regards bending, and this property, together with internal friction, is sufficient to suppress the radial modes in the lower frequency range, that is below 2,000 cycles per second. If the paper is thinner, for example 0.01 in. thick, radial modes in the lower frequency range tend to become troublesome.

Paper, whether plain or impregnated with hardening resins, does not have a very high wave transmission velocity. The value of this velocity is given by the square root of the ratio of the Young's modulus to the density. In the best Kraft paper the velocity is 1.7×10^5 cm. per second, and impregnating this paper with a hard resin may increase this value to 2.5×10^5 cm. per second. The high-frequency response of a conical diaphragm depends on this value of wave velocity, a low value giving a low cut-off frequency and vice versa. At frequencies exceeding 2,000 cycles per second, wave transmission begins to become apparent in a large conical diaphragm. It is necessary that this type of transmission should occur, since it reduces the effective mass of the diaphragm. In an ideal diaphragm wave transmission would take place without wave reflection, all the energy being radiated before the wave reached the boundary of the diaphragm.

Hitherto attempts have been made to use aluminium, which has a higher ratio of Young's modulus to density than paper (its wave transmission velocity being about 5.1×10^5 cm. per second), for conical diaphragms, but such diaphragms have proved unsatisfactory on account of radial modes and strong reflections. These defects are due to the high density of aluminium, compared with paper, which necessitates the use of thin material about 0.0025 in. thick, and to the small internal friction of such a diaphragm. The radial modes therefore appear at low frequencies and tend to cause the diaphragm to rattle.

A known conical aluminium diaphragm has a small number of widely spaced concentric depressions, or half corrugations with uncorrugated portions between them. This arrangement is not satisfactory, since reflection occurs at the corrugations and the metal between the corrugations buckles under the stresses imposed by normal operation and emits rattling sounds similar to the noise made by shaking a thin sheet of metal.

It has been proposed to use a conical diaphragm of aluminium or aluminium alloy having continuous corrugations in its surface. The corrugations were, however, of such a shape and depth that portions thereof lay substantially in planes normal to the direction of vibration of the diaphragm.

It has also been proposed to employ as a large acoustic diaphragm a rectangular sheet of aluminium or aluminium alloy highly tensioned longitudinally and provided with corrugations arranged in parallel rows transversely of the direction of the tensioning force. These corrugations, which may be provided over the entire surface or only at the ends of the diaphragm, are initially of small radius of curvature and are flattened to a large radius of curvature in the tensioning process.

It has further been proposed to provide a small aluminium diaphragm, for use in talking-machine sound-boxes or loud-speaking telephone receivers, having angular corrugations over the whole or a part of its surface, the diaphragm thus having the form of a series of truncated cones. The diaphragm, as a whole is conical, and the corrugations decrease in depth towards the centre.

An object of the present invention is to provide a large diaphragm which has a good response to the higher as well as to the lower acoustic frequencies.

A further object is to provide a large metal diaphragm in which the disadvantage hereinbefore referred to is obviated.

According to the present invention a large acoustic diaphragm is formed wholly or partly of a material having a higher ratio of Young's modulus to density than paper and is provided with corrugations disposed in paths curved around the driving point or zone (as distinct from being disposed in parallel straight rows) and merging into one another over at least a part of the surface of this material, the ratio of the pitch of the corrugations to the depth thereof (measured from trough to crest) being greater than 5 to 1.

According to the invention in a further aspect, a large acoustic diaphragm is formed substantially wholly of a material having a higher ratio of Young's modulus to density than paper and provided with corrugations disposed in paths curved around the driving point or zone and merging into each other over at least the radially outer portion of its surface, the ratio of the pitch of the corrugations to the depth thereof being not less than 8 to 1.

According to the invention in yet another aspect, a large acoustic diaphragm comprises a radially inner portion formed of a material having a higher

ratio of Young's modulus to density than paper, this portion being provided with corrugations disposed in paths curved around the driving point or zone and merging into one another over at least a part of its surface, the ratio of the pitch of the corrugations to the depth thereof being greater than than 5 to 1. The radially outer portion of this diaphragm is preferably of paper and of frusto-conical form.

It is preferred to make the improved diaphragms of conical or frusto-conical or other dished form, and where such a form is employed, it is advantageous to make the corrugations in the form of merging curves of such shape that all parts thereof lie at a considerable angle to planes normal to the direction of vibration of the diaphragm.

The region nearest to the driving point of a conical diaphragm or driving zone of a frusto-conical diaphragm may be uncorrugated or provided with corrugations of smaller depth, or longer pitch, or both, than those on a region farther from the driving point or zone. Where the region nearest to the driving point or zone is uncorrugated the material may be thicker here than elsewhere. Alternatively in a frusto-conical diaphragm the smaller diameter end may have the form of a cylindrical metal spigot flared out of the frustum so as to provide the necessary rigidity.

When vibrated at high frequencies, say from about 1,500 cycles per second upwards, a cone of, for example, 7 in. diameter acts in the manner of a mechanical transmission line, the impedance of which increases from the centre outwards. In order to avoid the formation of pronounced standing waves in the diaphragm, the latter must represent a smooth mechanical transmission line. It is therefore necessary to avoid a sudden change of mechanical impedance along the cone radius, such as would occur if the corrugations were deep. The corrugations should consequently be made as shallow as possible, consistent with freedom from rattle. It is also necessary to terminate the mechanical line with a suitable resistive element of approximately the same impedance as the cone. In this way the formation of pronounced standing waves due to reflection from the periphery of the diaphragm is prevented.

A preferred arrangement to prevent appreciable reflection from the periphery is to mount the edge of the diaphragm within a circular aperture in a box or baffle with the aid of an annulus of velvet or the like, there being interposed between the annulus and the diaphragm a layer of a substance which offers high internal friction to distortion due to vibrations and which is capable of withstanding considerable distortion within the elastic limit. A suitable substance is a highly plasticised vinyl acetate polymer, a suitable plasticiser being tricresyl phosphate.

In order to damp vibrations within the diaphragm, it may be formed with one or more joints incorporating a damping substance such as the above mentioned polymer.

The invention will be further described with reference to the examples shown in the accompanying drawings, in which

Fig. 1 is a section of part of a metal frusto-conical diaphragm,

Figs. 2, 3 and 4 are diagrammatic sections of alternative forms of radial joint in the diaphragm shown in Fig. 1,

Fig. 5 is a diagrammatic section of an arrangement for mounting the periphery,

Fig. 6 is a section of part of a metal and paper frusto-conical diaphragm,

Figs. 7 and 8 are diagrammatic sections of alternative forms of circumferential joint in the diaphragm shown in Fig. 6.

Referring to Fig. 1, the diaphragm 1 is formed from a circular sheet of aluminium about 8 in. in diameter. After a central disc and a sector have been cut from it, the sheet is formed in known manner into a conical frustum by joining the two radial edges 2 and 3, the apex angle of the frustum being about 105 deg. The joint is made by applying the vinyl acetate polymer softened by heat and lapping the edges. The frustum is then placed in a press and corrugated. While the diaphragm is in the press, the smaller diameter end is drawn into a cylindrical spigot 4 to receive a driving coil former, being flared about a relatively large radius. The corrugations are concentric with the cone and extend from the periphery inwards for about two-thirds of the distance from the periphery to the spigot, the radially inner portion being uncorrugated. The corrugations are formed by merging arcs of which the radius r is 0.4 in. and the depth d is 0.015 in. The pitch p is thus about 0.3 in., and the ratio of pitch to depth is about 20 to 1. Further, the corrugations are all of such shape and depth that no parts thereof approach parallelism to planes normal to the direction of vibration of the diaphragm as a whole, that is normal to the axis 5 of the frustum.

Owing to the reaction following the stretching process of drawing the spigot, the metal of the spigot is put into circumferential compression and the metal in the zone immediately adjoining the

spigot is put into circumferential tension. This prevents the occurrence of slackness over any small area of the radially inner part of the diaphragm and obviates crackling noises during operation.

The aluminium has the following properties: Breaking stress, 9 to 10 tons per square inch; Young's modulus 7.3×10^{11} dynes per sq. cm. For this aluminium cone of about 7 in. in diameter the thickness is preferably 0.0025 in. Radial modes have been found to become prominent in diaphragms of this kind if the thickness exceeds 0.004 in. and the diaphragm becomes too fragile if the thickness is below 0.0015 in.

The value of the square root of the ratio of Young's modulus to density for this quality of aluminium is about 5.1×10^5 cm. per second, whereas the corresponding value for paper is about 1.7×10^5 to 2.5×10^5 cm. per second as previously stated.

The aluminium used in constructing the above diaphragm is known as semi-hard. If harder material is used it will be found to have become too hard (and therefore liable to fracture in use) after the corrugations have been formed if these are formed in the cold. A softer material has not sufficient strength to withstand sudden low frequency impulses such as may be met with in practice. If the material is annealed during the corrugating process it may be possible to use a harder material. In any case endeavour should be made to arrange that when the corrugating process has been finished the material of the diaphragm has the highest possible degree of hardness consistent with capacity to resist alternating stress without fracture.

In order to damp circumferential vibrations, the diaphragm shown in Fig. 1 may be modified by the provision of a plurality of radial joints, for example four, spaced at equal intervals, and incorporating a damping substance. These joints may be plain lapped joints, as previously described. Alternative forms of joints are shown in Figs. 2, 3 and 4. In Fig. 2, the lapped edges 2 and 3 are united by a layer 6 of plasticised vinyl acetate polymer reinforced by thread stitches 7. Fig. 3 shows a folded joint, with the vinyl acetate polymer 6 lying between the folded edges 2^1 and 3^1. In Fig. 4 the edges 2 and 3 are butted and joined by a butt strap 6^1 of resistance material, which may be the vinyl acetate polymer. The diaphragm provided with such joints consists, nevertheless, substantially wholly of metal.

The driving coil former is attached to the spigot by cellulose cement, and the leads to the driving coil are secured to the former and not to the cone, to avoid rattling. The diaphragm is supported at its centre in known manner by means of a spider and it is mounted within an aperture 8 (Fig. 5) in a box or baffle 9 with the aid of a ring 10 of velvet attached by means of plasticised vinyl acetate polymer 6 to the periphery of the diaphragm 1. The velvet ring 10 may be impregnated with this polymer, which may be dissolved in methylated spirit or benzol and applied cold.

An alternative form of diaphragm is generally similar to that described with reference to Fig. 1, except that it has no radial joints. Furthermore, the spigot may be shorter, the necessary stiffness being provided by making the metal of the radially inner zone thicker than elsewhere. Thus the conical blank may be spun from a sheet of a thickness equal to the maximum thickness of the finished diaphragm, the radially outer portion being drawn thinner by the spinning operation. Alternatively the conical blank may be formed from a flat sheet by a series of drawing operations interspersed with annealing operations, by which the thickness can be graduated as desired.

In a modified diaphragm according to this invention, which however has not been found quite so satisfactory as that shown in Fig. 1, the size and material are the same but the corrugations over the outer two thirds of the diaphragm surface are formed by merging arcs of 0.21 in. radius and are of depth, from crest to trough, of 0.04 in. In this case the pitch is about 0.36 in. and the ratio of pitch to depth is therefore about 9 to 1. The inner one-third of the cone surface is provided with a little more than one shallow corrugation of about 0.03 in. in depth formed by merging arcs of 1.25 in. radius. The pitch is thus about 0.95 in. and the ratio of pitch to depth is 32 to 1.

Instead of the corrugations in the diaphragm being of only two different pitches, the pitch may become progressively smaller from the centre region around the driving coil outwards. The depth of the corrugations may also increase progressively from the centre outwards. The best results, however, have been attained when the ratio of pitch to depth has been between 15 to 1 and 25 to 1.

The functions of the corrugations are to remove irregularities from the surface of the diaphragm, to increase the lowest frequency at which radial modes of vibration take place and to give the diaphragm the stiffness necessary for safe handling.

It is therefore important that, at least in the outer region of the diaphragm, the corrugations should merge into one another and should not be spaced widely apart by uncorrugated portions.

Fig. 6 shows a further form of diaphragm having a radially inner portion 1^1 of aluminium and a radially outer portion 11 of paper. The maximum diameter is about 7 in. and the frustum of paper 11 extends from the periphery to the mid point between the periphery and the spigot 4, being joined at 12 to the aluminium portion which is 0.0025 in. thick and provided with corrugations of the same section as those shown in Fig. 1 and extending from the joint 12 to about the mid point between the joint and the spigot. The joint 12 shown in Fig. 6 is lapped, a resistance material, for example plasticised vinyl acetate polymer, being used as the adhesive. The joint may, if desired, be reinforced, for example by sewing with thread. Alternative forms of resistance joints between the aluminium and the paper are shown in Figs. 7 and 8. In Fig. 7 the paper and the aluminium cones are flanged, the resistance material being employed to couple the flanges together. In Fig. 8 the two portions are lap jointed and secured by a relatively rigid adhesive 13, such as cellulose cement, the joint being coated with a damping layer of the resistance material 6.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1 A large acoustic diaphragm formed wholly or partly of a material having a higher ratio of Young's modulus to density than paper, and provided with corrugations disposed in paths curved around the driving point or zone and merging into one another over at least a part of the surface of said material, the ratio of the pitch of the corrugations to the depth thereof being greater than 5 to 1.

2. A large acoustic diaphragm formed substantially wholly of a material having a higher ratio of Young's modulus to density than paper and provided with corrugations disposed in paths curved around the driving point or zone and merging into one another over at least the radially outer portion of its surface, the ratio of the pitch of the corrugations to the depth thereof being not less than 8 to 1.

3. A large acoustic diaphragm the radially inner portion of which is formed of a material having a higher ratio of Young's modulus to density than paper, said portion being provided with corrugations disposed in paths curved around the driving point or zone and merging into one another over at least a part of its surface, the ratio of the pitch of the pitch of the corrugations to the depth thereof being greater than 5 to 1.

4. A diaphragm as claimed in claim 1, 2 or 3, which is of conical or frusto-conical form, the angle subtended by the periphery of the cone at the apex thereof being substantially 105 deg.

5. A diaphragm as claimed in claim 3 or 4, the radially outer portion of which is made of paper and is of frusto-conical form.

6. A diaphragm as claimed in claim 4 or 5, wherein the corrugations are in the form of merging curves and are of such shape that all parts thereof lie at a considerable angle to planes normal to the direction of vibration of the diaphragm.

7. A diaphragm as claimed in claim 4, 5 or 6 wherein the region nearest to the driving point or zone is either uncorrugated or has corrugations which are of smaller depth than those in a region farther from said point or zone.

8. A diaphragm as claimed in claim 7, wherein the region nearest to the driving point or zone is uncorrugated and of thicker material than the radially outer portion of the diaphragm.

9. A diaphragm as claimed in claim 7, which is of frusto-conical form and of which the smaller diameter end has the form of a cylindrical metal spigot flared out of the frustum in such a manner as to put the spigot into circumferential compression and the metal in the zone immediately adjoining the spigot into circumferential tension.

10. A diaphragm as claimed in any one of the preceding claims, wherein the ratio of pitch to depth of the corrugations is between 15 to 1 and 25 to 1.

11. A diaphragm as claimed in any one of the preceding claims formed with one or more joints incorporating a substance which offers high internal friction to distortion and which is capable of withstanding considerable distortion within the elastic limit.

12. A diaphragm as claimed in any one of the preceding claims in combination with a mounting ring attached to the periphery thereof by means of a cementing substance which offers high internal friction to distortion and which is capable of withstanding considerable distortion within the elastic limit.

13. Apparatus as claimed in claim 11 or 12, wherein the said substance is a highly plasticised vinyl acetate polymer.

14. An acoustic diaphragm substantially as herein described, or as shown in the accompanying drawings.

Dated this 4th day of November, 1933.

REDDIE & GROSE,
Agents for the Applicants,
6, Bream's Buildings, London, E.C. 4.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1934

[This Drawing is a reproduction of the Original on a reduced scale.]

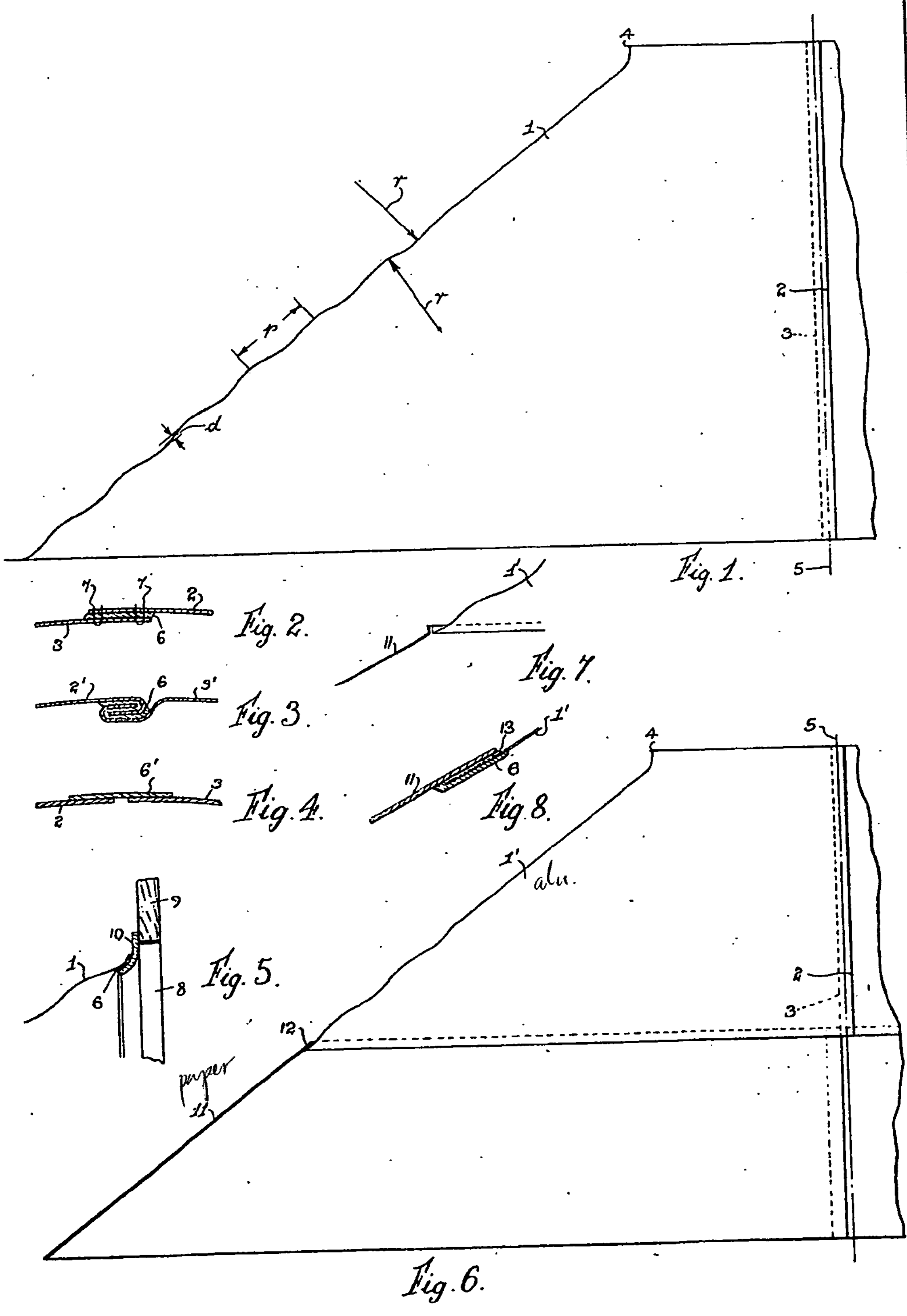

Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8.